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V. R. Eshleman
Project Director

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RESEARCH AT THE STANFORD CENTER FOR RADAR ASTRONOMY

The major support for research at the Stanford Center for Radar Astronomy is NASA sustaining grant NGL 05-020-014. Brief semi-annual reports, such as this one, are made in January and July and a complete description of the year's work is given in the annual proposal for continued support (e.g., Stanford proposal RL 9-69, March 1969). Faculty, research associate and student activities are reported in the following pages and the report concludes with a bibliography of publications and technical reports for January 1968 through June 1969.

Bistatic-Radar

Work has continued on the reduction and analysis of the bistatic-radar data from Explorer XXXV. The principal block of data from the observations using the Stanford Research Institute/SCRA 150' dish has now been completed. Current efforts in data reduction are directed toward obtaining very high quality bistatic-radar spectra, representative of various portions of the lunar surface, from the Arecibo observations. The original flight contract has just been completed. Further analysis and interpretation is being supported by a grant from NASA Headquarters which has provision for partial reduction of the bistatic-radar observations conducted with Lunar Orbiters I and III under the sustaining grant.

The principal result of this work in this reporting period is the bistatic-radar measurement of topographic variations in lunar slope statistics based on the Explorer XXXV observations. We obtain values of 2°, 3° and 6° for the rms uni-directional slopes on the scale of 100 m in Mare Fecunditatis, the central highlands, and the Censorenus highlands, respectively. These results are considerably lower, by factors of 3 to 5, than previous estimates of of slopes from ground based radar observations. A critical analysis of both the ground based and bistatic results has been undertaken to resolve this discrepancy. At the moment it is felt that the difficulties in determining the position of the leading edge of the pulse return and use of (~) 10 μsec pulses in previous work is an uncompensated instrumental effort in the ground based measurements.

Considerable effort, under the sustaining grant, has been directed toward the interpretation of radar results in geological and geophysical terms. It is now believed that properly designed radar experiments can provide meaningful constraints and evidence on lunar subsurface structure. This work has led to two Apollo program proposals, one for downlink experiments using the S-band communications system and the other, uplink, using a receiver similar to the Pioneer and Mariner instruments on board Apollo to receive transmissions from Stanford. The first of these is designed to measure the Brewster angle of the lunar crust. The uplink experiment is designed to detect impedance constrasts between adjacent or layered geologic units to depths of at least 200 meters. Detection of inhomogeneities in the regolithic material is also probable through consideration at depolarization effects. The experiment is designed to operate in the radiometric mode during periods when out of Stanford's view or behind the moon. This will produce a continuous map of lunar reflectivity (the reflection of cosmic noise from the surface) at two of the lower frequencies and a map at lunar surface temperature with a resolution of $1^{\circ}C$ at 425 MHz.

Both proposals have survived the initial selection processes and are now under active study at the MSC.

Flight Programs

The Stanford ground station is presently taking data 60-70 hours per week on Pioneers 8 and 9. Pioneer 9 passed the one AU mark on June 20 on its way to superior conjunction in November 1970. The instrument is performing perfectly and has produced evidence of very large solar streams. A signal to noise margin of 2 to 3 db is projected for superior conjunction, thus the next year should prove to be very interesting.

Ionospheric data in support of the Pioneer program is currently being taken from a VHF receiving system which measures the polarized angle of the Applications Technology Satellite 136 MHz transmissions. Several of these polarimeters are in operation and a technical report on their design is being prepared. One has recently been installed at the Venus site (Station 13) to provide data backup for the Mariner 6 and 7 Mars flyby. Several more are under construction and will be used to provide more complete ionospheric information along the Stanford-Pioneer raypath.

Correlation between Stanford Pioneer and Mariner data and that produced by the ATS receivers has shown that the ultimate accuracy of planetary probe ranging systems is limited by plasma effects. Further, correlation with S-band doppler residuals demonstrates this conclusively in that 10 meter errors can be caused by plasma along the propagation path. Thus, it is clear that ranging to the desired accuracy of 1 meter can only be achieved through dispersive techniques.

Interstellar Electron Density

Using the Stanford 150' dish and the Lick Observatory 120" telescope, simultaneous radio and optical observations of Pulsar NP 0532 have been made. The two stations were synchronized in time to ± 50 microseconds by use of a VHF radio link. The conclusion reached is that the optical and radio emissions occur within a few milliseconds of each other. The accuracy limit is set by our precise knowledge of the true dispersion. Alternatively, we can assume that the optical and radio pulses are emitted simultaneously. We can then derive an accurate value for the interstellar electron density from the 1.31249 second dispersive delay between the two. The number derived from this is $1.7542 \pm 0.0003 \times 10^{20}$ electrons cm^{-2}.

Student Activities

The following brief reports are representative of graduate student activity.

John Albernaz

With respect to the ATS satellite circuit between Stanford University and the Comissao Nacional de Atividades Espaciais (CNAE) in Brazil, feasibility studies were conducted during the last quarter. In addition, link calculations were made and two alternative systems for transmitting information were put forward.

This proposal has been forwarded to NASA and we are awaiting approval.

Jorge Heraud

Most of the time since the last report has been devoted to coding, debugging and improving the programs for data processing. This involved digitizing the data in analog form to produce a digital tape and then processing this information in a non-real time fashion. Many of the problems arose from computer memory limitations, which made use of the magnetic disk for partial storage mandatory. The moon experiment that had been recorded on magnetic tape was used to debug and optimize the computer programs. Due to the fact that when the moon experiment was carried out the frequency synthesizer was not capable of coherent recycling because of a manual blanking problem, the data processing scheme turned out to be more complicated than originally thought.

An automatic blanking circuit has already been devised and modifications in data processing for the ionospheric experiments are now being implemented. The new experimental parameters are somewhat different as in the case of the moon. The length of the pseudo-random code is 63, which implies a shift register length of 6 and the basic frequency shift is 100 Hz. The spectral width is 6.3 kHz. The transmitter pulse length is now 3.15 msec, and the duty cycle 25 permitting a maximum range of almost 1900 km.

Daniel Ingalls

Since the last report I have been spending much of my time investigating the properties of Hadamard transforms. These transforms can be computed faster than Fourier transforms yet possess several of the same useful properties. I have derived a matrix which expresses one transform in terms of the other. By examining this matrix it should be possible to judge the appropriateness of the Hadamard transforms.

A subject which recently attracted my attention is that of holographic contour generation. This is an optical method in which a hologram is made of an object using two wavelength of illumination. The hologram is then projected with one wavelength so that the two images have slightly different longitudinal magnification. The interference between the two superposed images leads to interference fringes which delineate constant depth contour lines on the original object. An attractive subject for investigation is the extension of this method to side-looking radars. If the technology appears reasonable, this would be a simple method for contour mapping on the earth and for planetary surfaces.

Jon Jenny

The UGO (Unmanned Geophysical Observatory) project is continuing on schedule. The data encoder circuit design is complete and has been frozen. All parts have been ordered and most have arrived. All the printed circuit cards have been laid out and all the masks have been made. Special purpose equipment has been built to fuse and test diode matrices and to simulate the command decoder. The principal remaining jobs are to mount the components on the printed circuit cards and to finish the back panel wiring.

Continued investigation of the power supply problem has indicated that a windmill will be the cheapest source of power. A windmill which seems to meet the needs of this station is available from Dunlite Company in Australia. The best available model is a "brushless" type which has high reliability and creates very little radio frequency interference. This windmill is designed to survive a 140 mph wind and costs about $1,500 excluding the tower. A trade-off study is being made to determine the best type of battery and the number of batteries required to furnish power during calm periods.

Jeremy Landt

Signals at 50 and 423 MHz are sent to Pioneer 6, 7, 8 and 9 and Mariner 5 in deep space. From the differential group delay and phase advance of the radio signals the integrated electron content between the ground transmitter and the receiver on the spacecraft can be determined, both average values and particular events are of interest. I am presently looking at the records of integrated electron content and relating these measurements to some of the parameters of the solar wind such as bulk velocity and electron number density. The removal of ionospheric effects is done by using ATS satellite measurements, which is not always straightforward. Work is continuing in this area. During the peak of solar activity, several large increases in content have been measured. By combining our measurements with measurements made by others, the spacial structure of these events can be studied, thus learning something of the nature of solar flares which are thought to cause at least some of the events.

Angus Morrisson

Radioscience Laboratory report no. SU-SEL-68-038 describes an experiment to provide global weather prediction using radio wave measurements between two satellites. Of utmost importance in the experiment is having the capability to furnish accurate estimates of the satellites position relative to the earth throughout the mission. As is the case with most estimation problems, a reasonable model for the system dynamics must be obtained. For the proposed experiment, this involves finding a good mathematical model for the differential equations of motion for the satellites.

Of particular difficulty is modeling the effect of atmospheric drag upon the motion of the satellite. Although the drag force per unit mass at the altitude of the weather satellites (about 1100 km) is only about 10^{-10} g, its cumulative effect would produce significant errors in less than two weeks. Future studies are planned to determine with what degree of accuracy this drag perturbation can be predicted.

Currently, a large amount of research is being devoted to determining how well the earth's gravitational field can be modeled. Because of the accuracy needed for the radio wave measurements, the longitudinal dependence of the earth's potential must be taken into account. Amplitudes of over 75 meters have been calculated for some of the tesseral harmonics in the earth's gravitational field. Methods of using the weather satellite data to enhance present-day knowledge of the differential harmonic coefficients is also being investigated.

Michael Olson

A prototype design for a remote-controlled unmanned geophysical observatory for use in Antarctica is being completed. The work effort is presently being directed towards generating the engineering specifications for a satellite relayed telemetry data link and a remote control command link. Successful completion of this system will enable year-round access to areas of the Antarctic continent that are normally accessible only during the austral summer.

Jose Pomalaza

Work on occultation satellites was continued. Attenuation in the atmosphere was studied and its use to correct for the water vapor effect in the phase measurements was analysed.

Our inversion program to invert phase defect data was modified so that it includes the absorption and correction for water vapor. A simulation was carried out. Rawindsond measurements taken in Oakland in the summer of 1966 were used to simulate atmospheric conditions. It was found that without correcting for water vapor, climatology can be used to extend the occultation measurements below the 300 mB level. Using the absorption to correct for the water vapor, the pressure profile was measured with 2.5 mB accuracy up to the 700 mB level.

Richard Simpson

Over the past six months work has been divided two ways; first, on a feasibility study of a dual frequency, monostatic, moonbounce experiment; and, second, on data processing for the bistatic lunar radar project headed by Dr. Tyler.

The proposed moonbounce experiment was suggested in a recent Stanford doctoral thesis by Dr. Alan Burns[1]. Through careful study of the many parameters affecting the return of radar signals from the moon, he concluded that the location of the sub-earth point was considerably more important than had previously been thought. In fact, the leading edge of the return was down 3 db or more when the sub-earth point was in highland areas as compared with maria. Preliminary study showed that a month long dual frequency experiment would be valuable in terms of both verifying Burns' theory and studying an area at more than one wavelength. This project has now moved into a study of the possible ways to conduct such an experiment.

The bistatic radar study of the moon is under a separate contract but relies on the sustaining grant for some of its support activities. At present data has been reduced and checked, and interpretation is beginning. One of the more interesting approaches to reduction-interpretation has been through use of contour plots. It has been found that surface features influence the half-power bandwidth of the reflected signal. If data points are interpolated into a uniform grid, contour plot subroutines supplied by the Stanford Computation Center can be used. Plotted to the same scale as available photographs of the lunar surface, the contour plots make good overlays. In this way the differences between rough and smooth areas can be strikingly demonstrated. For example, parts of the Censorinus Highlands appear to be four times as rough as neighboring Mare Fecunditatis. An extension of these methods to creating contours of an arbitrary projection of the surface is now being completed.

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[1] Burns, A., Lunar Radar Scattering at 6 and 12 Meter Wavelengths, Scientific Report No. 25, NSG 377, SU-SEL-68-005, Stanford Electronics Laboratories, Stanford University, Stanford, California, May 1968.

Michael Sites

Communication with spacecraft and other power limited sensors over extreme ranges requires low data rates to maintain an adequate bit-energy-to-noise ratio. However, the performance of the resulting narrow-band system can be severely limited by medium and equipment instabilities.

By using coded discrete frequency sequences similar to discrete frequency codes employed in radar, acceptable performance may be maintained in the presence of instabilities which would render conventional communication systems useless. The behavior of these codes in fluctuating channels has been obtained and procedures for optimization discussed[1]. It is shown that when properly optimized these coded discrete frequency sequences can provide good performance over a large range of input SNR and channel fluctuation bandwidth

This low sensitivity coupled with incoherent detection permits this technique to be implemented without requiring channel estimation.

It is shown that by properly choosing the ambiguity function and cross-ambiguity function of the transmitted sequence it is possible to construct an orthogonal code alphabet with low cross-interference which permits M-ary communication. An algorithm for quickly obtaining the significant features of the ambiguity and cross-ambiguity function is developed as well as a technique for synthesizing codes from this simplified ambiguity function representation.

In addition to low data rate communication, the principles developed have application to radar systems using discrete frequency modulation which must operate with long pulses and/or against rapidly fluctuating targets. The algorithm for calculating the ambiguity function is particularly useful.

Further investigation into the properties of these sequences is planned using the techniques developed along with experiments to demonstrate the feasibility of the proposed techniques.

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[1] "Coded Frequency Shift Keyed Sequences with Applications to Low Data Rate Communication and Radar" (to be published).

Steven Ungar

My work on the Earth Occultation Project in the last half-year has been concentrated on improving the raytracing program which is used to simulate behavior of the system. The program has been revamped so that it now uses Snell's Law for computing differential progress of the ray, thus permitting horizontal gradients in the atmosphere to be taken into account.

In its present form the program accepts an atmosphere profile, which may have both horizontal and vertical gradients, raytraces through this atmosphere, and also raytraces through a set of horizontal displacements of the atmosphere, simulating the travel of the satellite system in its orbit. In addition, an auxiliary program has been developed to generate from the "real" atmosphere a set of spherically symmetric model standard atmosphere.

In addition to the above computer simulations, work has also progressed on meteorological statistics. A study of cloud distribution as a function of altitude, based on USAF data for the Soviet Union, has been completed. Work has begun on developing a standard profile of relative humidity as a function of altitude.

At present the raytracing program is being transferred to the SDS Sigma 5 computer. When the transfer is successfully completed, the data handling capacity of the program will be greatly expanded, giving us the capability of detecting fine-structure layering in the lower troposphere.

Robert Wang

Reduction of redundancies in the scan line signal of pictures have resulted in pictures of comparable quality with bandwidth reduction of 5:1 over PCM transmission. These techniques use redundancies in one dimension only, namely, horizontal redundancies. Redundancies in two more dimensions are available in the case of TV pictures - vertical redundancies and frame-to-frame redundancies.

One way to exploit the spatial redundancies is by using an entropy preserving, invertible, linear transform in the l_2-space. Using a buffer, it is possible to use a predictive system to remove frame-to-bandwidth (BW) requirements even further.

The two dimensional Fourier transform has been shown to preserve entropy[1]. Being also linear and invertible, it fits all the requirements mentioned previously. Another promising transform in l_2-space is the Hadamard transform. It is linear, invertible, and presumably entropy preserving. The attractive features of this latter transform are:

a) It consists of multiplying the picture elements (pel) by ± 1, and summing according to some rule (this is a function of the form of the Hadamard transform used).

b) For symmetric Hadamard matrices, H,

$$H = H^{-1}$$

This property simplifies the inverse transform process, since it is the same as the initial transformation of the information.

Both the Fourier and the Hadamard transforms in two dimensions have been shown as suitable vehicles by which images can be coded, transmitted, and reconstructed[2,3,4]. By threshold coding in the transform plane, BW reductions of 5:1 is possible with no "visible" deterioration of the picture. By virtue of the availability of two dimensional redundancies it would seem that even greater BW reduction should be possible without hurting the end result.

Many psychophysical properties of the human eye in response to different factors and errors in the picture has been studied by many researchers in the spatial plane[5]. It would be interesting to know how these errors are transformed into either the Fourier or Hadamard plane.

Problems that will be worked on:

a) Prove that the Hadamard transform is entropy preserving;

b) determine the relationships between errors in the picture (spatial plane) and that in the transform plane (transform being used in the general sense);

c) study the design of some transform coders.

References

1. Andrews, H. C., "Entropy considerations in the frequency domain", Proc. IEEE (letters), vol. 46, pp 113-114, January 1968.

2. Andrews, H. C. and W. K. Pratt, "Fourier transform coding of images", Hawaii International Conference on System Sciences, pp 677-679, January 1968.

3. - , "Television bandwidth reduction by Fourier image coding", presented at the Soc. of Motion Picture and Television Engineers, 103 rct Technical Conference, May 1968.

4. Pratt, W., K. J. Kane and H. C. Andrews, "Hadamard Transform Image Coding, Proc. IEEE, vol. 57, No. 1, pp 58-68, January 1969.

5. Schreiber, W. F., "Picture Coding", Proc. IEEE, vol. 55, No. 3, March 1967.

Appendix

Publications

Dyce, R. B., Radar Studies of the Planets, from Surfaces and Interiors of Planets and Satellites, ed. A. Dollfus, Academic Press, Paris (in press).

Fjeldbo, G., Ionospheres of Venus and Mars, from Encyclopedic Dictionary of Physics, ed. J. Thewlis, Pergamon Press, Oxford (in press).

Tyler, G. L. and H. T. Howard, The Refractivity of CO_2 under Simulated Martian Conditions, Radioscience (in press).

Eshleman, V. R., Bistatic Radar Astronomy, American Astronomical Society, vol. 24, 1969.

Vesecky, J. F., Radio Frequency Synchrotron Emission from Inner Belt Electrons, JGR, vol. 74, 1 July 1969.

Conklin, E. K., H. T. Howard, J. S. Miller, E. J. Wampler, Simultaneous Optical and Radio Observations of NP 0532, Nature, vol. 222, 552-553, 10 May 1969.

Eshleman, V. R., The Atmosphere of Mars and Venus, Scientific American, vol. 220, 78-88, March 1969.

Vesecky, J. F., Radio Frequency Synchrotron Radiation from Electrons Trapped above the Aurora Zone, Planetary and Space Sci., vol. 17, 389-403, March 1969.

Fjeldbo, G. and V. R. Eshleman, The Atmosphere of Mars: Radio Occultation Measurements and Interpretations, from The Atmospheres of Venus and Mars, ed. J. C. Brandt and M. B. McElroy, Gordon and Breach Science Publishers, 225-240, New York, 1968.

Tyler, G. L., Oblique-Scattering Radar Reflectivity of the Lunar Surface: Preliminary Results from Explorer 35, JGR, vol. 73, 7609-7620, December 1968.

Eshleman, V. R., G. Fjeldbo, J. D. Anderson, A. Kliore and R. B. Dyce, Venus: Lower Atmosphere Not Measured, Science, vol. 162, 661-665, 8 November 1968.

Tyler, G. L., Brewster Angle of the Lunar Crust, Nature, vol. 219, 1243-1244, 21 September 1968.

Conklin, E. K. and H. T. Howard, Simultaneous Observations of a Pulsating Radio Source over a 5,000 km Baseline, Nature, vol. 219, 1238-1239, 21 September 1968.

Koehler, R. L., Radio Propagation Measurements of Pulsed Plasma Streams from the Sun Using Pioneer Spacecraft, J. Geophys. Res., vol. 73, 4883-4894, 1 August 1968.

Publications (continued)

Fjeldbo, G. and V. R. Eshleman, The Atmosphere of Mars Analyzed by Integral Inversion of the Mariner IV Occultation Data. J. of Planetary and Space Sci., vol. 16, 1035-1059, July 1968.

Bollay, W. and B. B. Lusignan, Systems Engineering, J. of Engineering Education, 818-821, April 1968.

Technical and Scientific Reports

Arps, R., Entropy of Printed Matter at the Threshold of Legibility for Efficient Coding in Digital Image Processing, Sci. Rpt. No. 31, NGL 05-020-014, SU-SEL-69-012, Stanford Electronics Laboratories, Stanford, California, March 1969.

Tyler, G. L. and H. T. Howard, The Refractivity of CO_2 under Simulated Martian Conditions, Sci. Rpt. No. 33, NGL 05-020-014, SU-SEL-69-013, Stanford Electronics Laboratories, Stanford, California, March 1969.

Croft, T. A., Methods and Applications of Computer Raytracing, Tech. Rpt. No. 3903-112, SU-SEL-69-007, ONR 64, Stanford Electronics Laboratories, Stanford, California, January 1969.

Fjeldbo, G. and V. R. Eshleman, The Atmosphere of Venus as Studied with the Mariner V Dual-Frequency Occultation Experiment, Final Report, NGR 05-020-276, SU-SEL-69-003, Stanford Electronics Laboratories, Stanford, California, January 1969.

Crespo da Silva, M., Attitude Stability and Motions of a Gravity-Stabilized-Gyrostat-Satellite in a Circular Orbit, Sci. Rpt. No. 32, NGL 05-020-014, SU-SEL-68-103, Stanford Electronics Laboratories, Stanford, California, December 1968.

Jenny, J., Optimization of Unmanned Data Collection Systems, Tech. Rpt. No. 3433-1, NSF Grant 1195, SU-SEL-68-089, Stanford Electronics Laboratories, Stanford, California, December 1968.

Yu, W., Circuit Synthesis Utilizing Digital-Variable Precision-Integrating and Summing Elements, Sci. Rpt. No. 30, NGL 05-020-014, SU-SEL-68-084, Stanford Electronics Laboratories, Stanford, California, December 1968.

Tyler, G. L., The Calculation of Orbitally Determined Experimental Parameters from Bistatic-Radar Observations of Explorers XXXIII and XXXV from Classical Orbital Elements, Tech. Rpt. No. 3609-2, NAS 5-9347, SU-SEL-68-059, Stanford Electronics Laboratories, Stanford, California, June 1968.

Technical and Scientific Reports (continued)

Tyler, G. L., A Dual Polarization Bistatic-Radar Receiving System for Explorers XXXIII and XXXV, Tech. Rpt. No. 3609-3, NAS 5-9347, SU-SEL-68-008, Stanford Electronics Laboratories, Stanford, California, June 1968.

Barna, A., Pseudorandom Frequency Modulation in Range-Doppler Radar, Sci. Rpt. No. 29, NSG 377, SU-SEL-68-046, and Tech. Rpt. No. 3606-4, Stanford Electronics Laboratories, Stanford, California, May 1968.

Burns, A. A., Lunar Radar Scattering at 6 and 12 Meter Wavelengths, Sci. Rpt. No. 25, NSG 377, SU-SEL-68-005, Stanford Electronics Laboratories, Stanford, California, May 1968.

Thiede, E. C., Locating Refractive Index Variations with Bistatic-Radar, Sci. Rpt. No. 27, NSG 377, SU-SEL-68-037, Stanford Electronics Laboratories, Stanford, California, May 1968.

Lusignan, B. B., A Preliminary Study of Atmospheric Density Measurements by Means of Satellites, Final Report, NAS 9-7020, SU-SEL-68-038, Stanford Electronics Laboratories, Stanford, California, April 1968.

Jenny, J. A. and W. F. Lapson, Feasibility Study of an Automated Unmanned Geophysical Observatory for Operation in Antarctica, Tech. Rpt. No. 3431-1, NSF Grant 1195, SU-SEL-68-010, Stanford Electronics Laboratories, Stanford, California, February 1968.

Barna, A., Pseudorandom Frequency Modulation in Range-Doppler Radar Systems, Sci. Rpt. No. 26, NSG 377, SU-SEL-68-022, Stanford Electronics Laboratories, Stanford, California, February 1968.

Tyler, G. L. and A. M. Peterson, Report on Monitoring AIMP-D Stanford AIMP Telemetry Monitoring Experiment, Tech. Rpt. No. 3609-1, NAS 5-9347, SU-SEL-68-006, Stanford Electronics Laboratories, Stanford, California, January 1968.

Spira, P. M., On the Time Required for Group Multiplication, Sci. Rpt. No. 24, NSG 377, SU-SEL-68-003, Stanford Electronics Laboratories, Stanford, California, January 1968.

Symposia Attended and Papers Presented

Tyler, G. L. and E. A. Simpson, Bistatic Lunar Measurements of Topographic Variations in Lunar Surface Slopes with Explorer XXXV, IAU Symposium on Planetary Atmospheres and Surfaces, Woods Hole, Massachusetts August 1969.

Tyler, G. L. and H. T. Howard, The Refractivity of CO_2 Under Simulated Martian Conditions, URSI Symposium, Washington, D. C., April 1969.

Tyler, G. L., Probing Planetary Surfaces and Subsurfaces with Bistatic-Radar, Conference on Scientific Applications on Radio and Radar Tracking in the Space Program, Jet Propulsion Laboratory, Pasadena, California, 9-11 April 1969.

Nowak, R., On The Relationship between Decay Rate of Radar Echoes from Meteor Trails and Their Height, American Geophysical Union Meeting, San Francisco, 2 December 1968.

Nowak, R., The Measurement of Upper Atmosphere Parameters with a Meteor Radar, American Meteorological Society, El Paso, 6 November 1968.

Miles, R. B. and B. B. Lusignan, DEMETER, an Earth Resources Satellite Program, Proceedings of the 19th Congress of IAF, New York City, October 1968.

Lusignan, B. B., Education Satellite Technology, Proceedings of the 19th Congress of IAF, New York City, October 1968.

Eshleman, V. R., Bistatic Radar Studies of Planetary Atmospheres and Surfaces, G-AP/URSI Symposium, Boston, 10 September 1968.

Tyler, G. L., Short course: Imaging Radar, University of Michigan, Ann Arbor, July 1968.

Howard, H. T., Mariner V Experimenter Data Workshop, University of Iowa, June 1968.

Tyler, G. L., Past Results and Future Experiments in Radar Scattering, NASA-Ames Conference on Electromagnetic Exploration of Moon, Moffett Field, June 1968.

Lusignan, B. B., Density Measurement with Radio Wave Occultation Techniques COSPAR (Communications on Space Research), Tokyo, 9-21 May 1968.

Lusignan, B. B., AIAA - Systems Engineering, Houston, 20 May 1968.

Eshleman, V. R. and G. Fjeldbo, Radio Occultation and the Atmosphere of Venus and Mars, AGU, Washington, D. C., 8-11 April 1968.

Staff, Center for Radar Astronomy at Stanford University, The Mariner-Venus Dual-Frequency Radio Occultation Experiment: Current Interpretation, AGU, Washington, D. C., 8-11 April 1968.

Tyler, G. L., Preliminary Bistatic-Radar Results from Explorer XXXV, AGU, Washington, D. C., 8-11 April 1968.

Fjeldbo, G. and V. R. Eshleman, Mariner V Low Frequency Occultation, Second Arizona Conference on the Planetary Atmospheres, Tucson, 11-13 March 1968.

Fjeldbo, G., A. Kliore, I. S. Rasool, Mariner V S-band Occultation (with Respect to Upper Atmosphere), Second Arizona Conference on the Planetary Atmospheres, Tucson, 11-13 March 1968.

Lusignan, B. B., The Arctic Institute of North America Symposium on Remote Sensing in the Polar Regions, Washington, D. C., 6-8 March 1968.

Spira, P. M., On the Time Required for Group Multiplication, Hawaiian International Conference on Systems Sciences, 29-31 January 1968.